High resolution speleothem records of climatic change in northern Iberia, Cantabria, Matienzo

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Abstract

Records of climatic change from northern Iberia provide detailed information on connections between circulation in the North Atlantic ocean and prevailing climatic conditions. However, despite stalagmites being able to provide some of the best records of past environmental and climatic change, very few have been investigated in detail in this location. The Matienzo depression in Northern Spain contains active speleothem deposits and has provided an opportunity for climate reconstruction over the past 12,000 years. Monitoring of conditions within Cueva d'Asiul has shown this cave to be ideally suited to recording environmental signals within the stalagmites. The two stalagmite records obtained show a climatic history which supports known archaeological events in the region and is seen to be controlled by changing patterns of ocean circulation in the North Atlantic. These records form some of the most continuous, detailed archives of climate history known in the region.

Introduction

Cueva de Asiul is a small cave system located near the village of Matienzo in Cantabria. Monitoring of the cave has been undertaken since 2010 as part of a PhD project based at Lancaster University, UK. The project aims to characterise cave environmental conditions, and analyse two stalagmites which reveal climatic changes in Northern Spain during the past 12,000 years. Currently, stalagmite analysis indicates that Northern Spain has experienced periods of significant change in the amount of rainfall, closely linked to changes in the North Atlantic Ocean. Based on our current age model, a significant period of aridity is identified between 7000 and 5000 years BP, during an important period for human development in the region. The chronology of events recorded within the speleothem is subject to further revision due to ongoing work. This report outlines the main results of both cave monitoring and stalagmite analysis, as of April 2013.

Cave Monitoring

Chemical records contained within stalagmites reflect the atmospheric climate at the time of growth. However, the record becomes complicated due to modification of chemical signals in the soils and bedrock above the cave. For this reason, the atmospheric climate, cave hydrology and internal cave conditions are being monitored to understand how the stalagmites in Cueva de Asiul can reflect climatic change over the past 12,000 years. Monitoring activity has involved: (1) the collection of rainfall in Matienzo between 2011 and 2013; (2) logging and collection of drip waters from Cueva de Asiul; (3) the measurement of temperature and carbon dioxide within the soil and cave; (4) the removal of two stalagmite samples for palaeoclimate analysis.

Monitoring of rainfall and cave drips indicates that Cueva de Asiul is closely connected to the external environment. Periods of high rainfall during the winter cause a rapid change in drip behaviour, increasing the volumes of water entering the cave. Dry conditions throughout the summer create low water levels within the cave system (Figure 1).

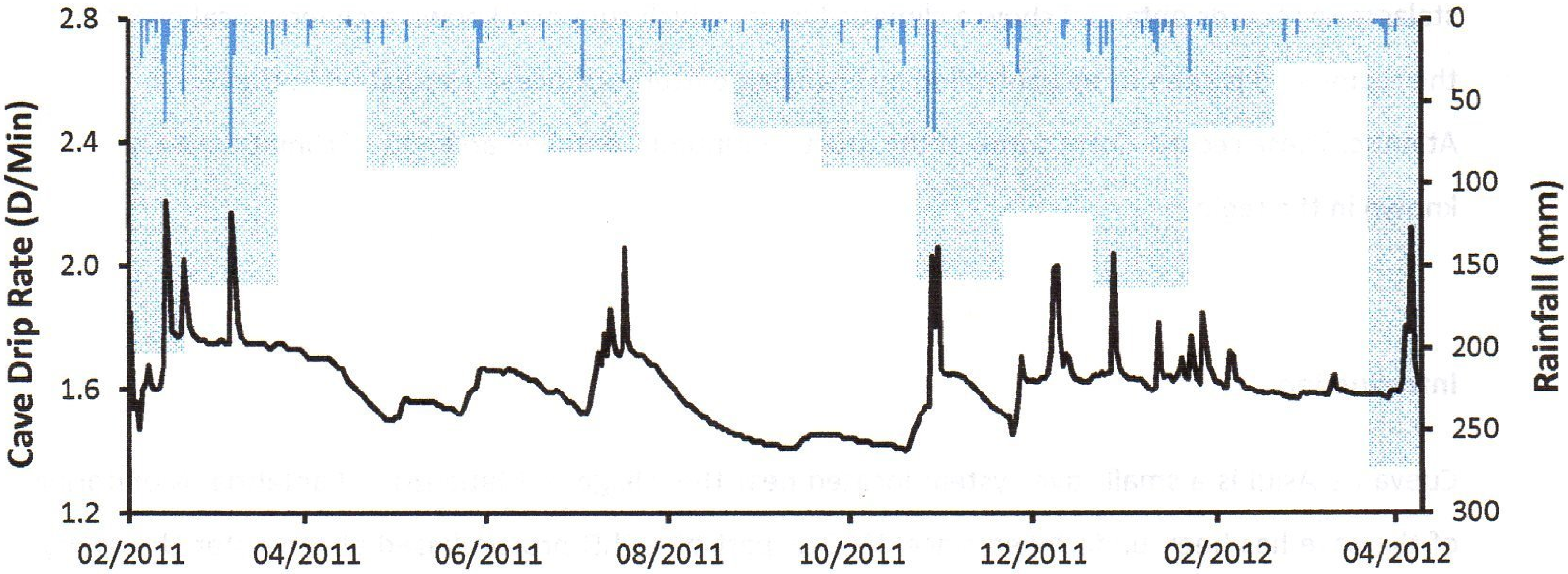

Figure 1: Precipitation amount, blue boxes represent monthly average precipitation and thin blue lines are event data. Black line represents number of drips per minute at one cave drip site in Cueva de Asiul.

Winter rainfall which does not immediately reach the cave is stored within the bedrock overlying Cueva de Asiul. This water is slowly released during the summer, meaning that stalagmite formation occurs throughout the year and provides a continuous chemical signal of climatic change.

Conditions of temperature and air within Cueva de Asiul also show a strong connection to the external environment. Cave temperature (13.2 ± 0.5 °C) closely mimics the average external temperature (13.9 °C), whilst carbon dioxide concentration is influenced by both soil microbiological activity and air movements within the cave (ventilation). Cueva de Asiul is very sensitive to changes in external climate, meaning stalagmites from deep within this cave are ideal for the analysis of past climatic change.

Stalagmite Chronology

Two stalagmite samples from Cueva de Asiul are being dated at high resolution using U/Th decay at the NERC Isotope facility, UK. On completion, these two samples will be constrained by 31 U/Th ages. The partial chronology from both samples is shown in figures 2 and 3 below.

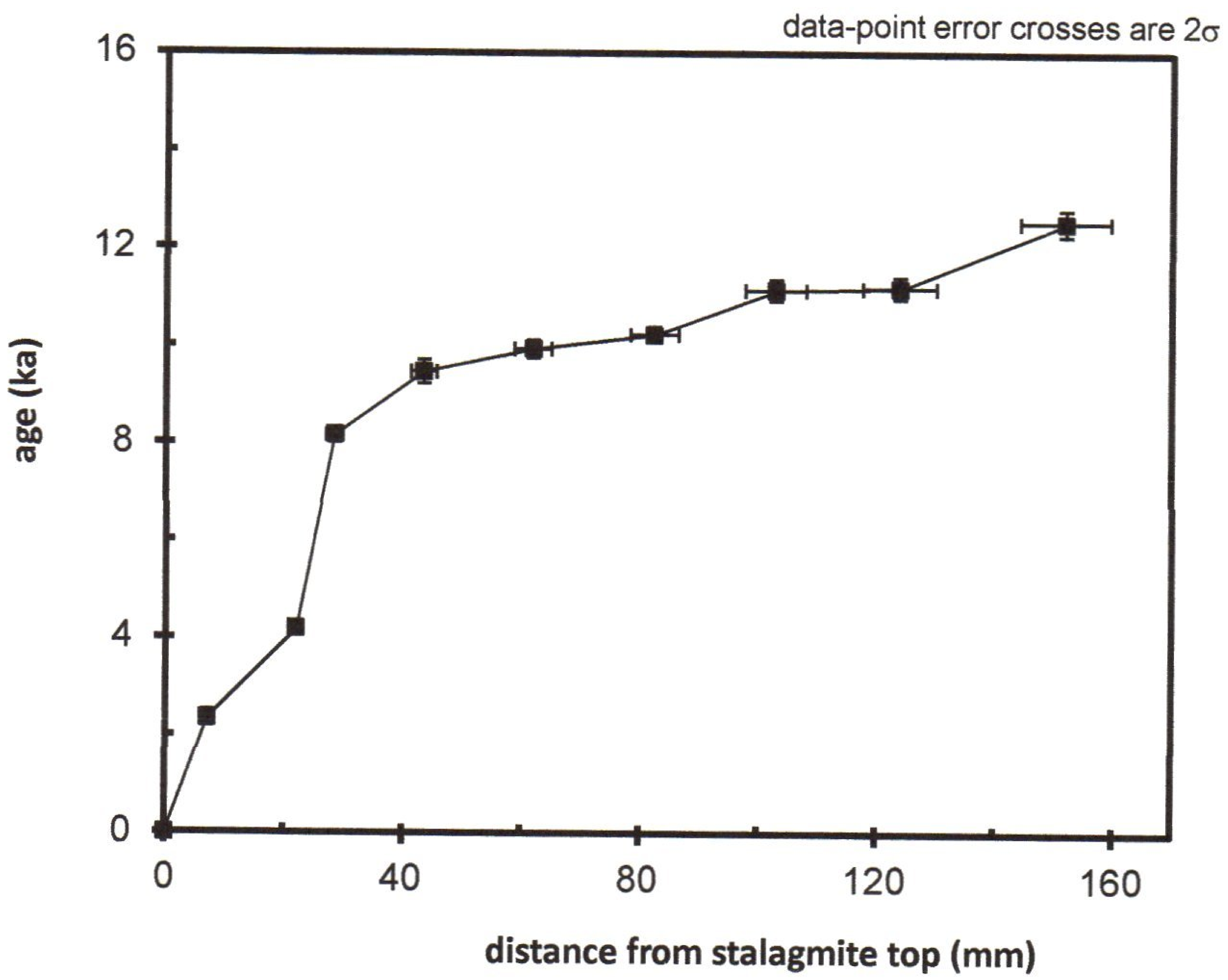

Figure 2: Preliminary age model for speleothem ASR developed from 9 U/Th analyses over 16cm of speleothem carbonate.

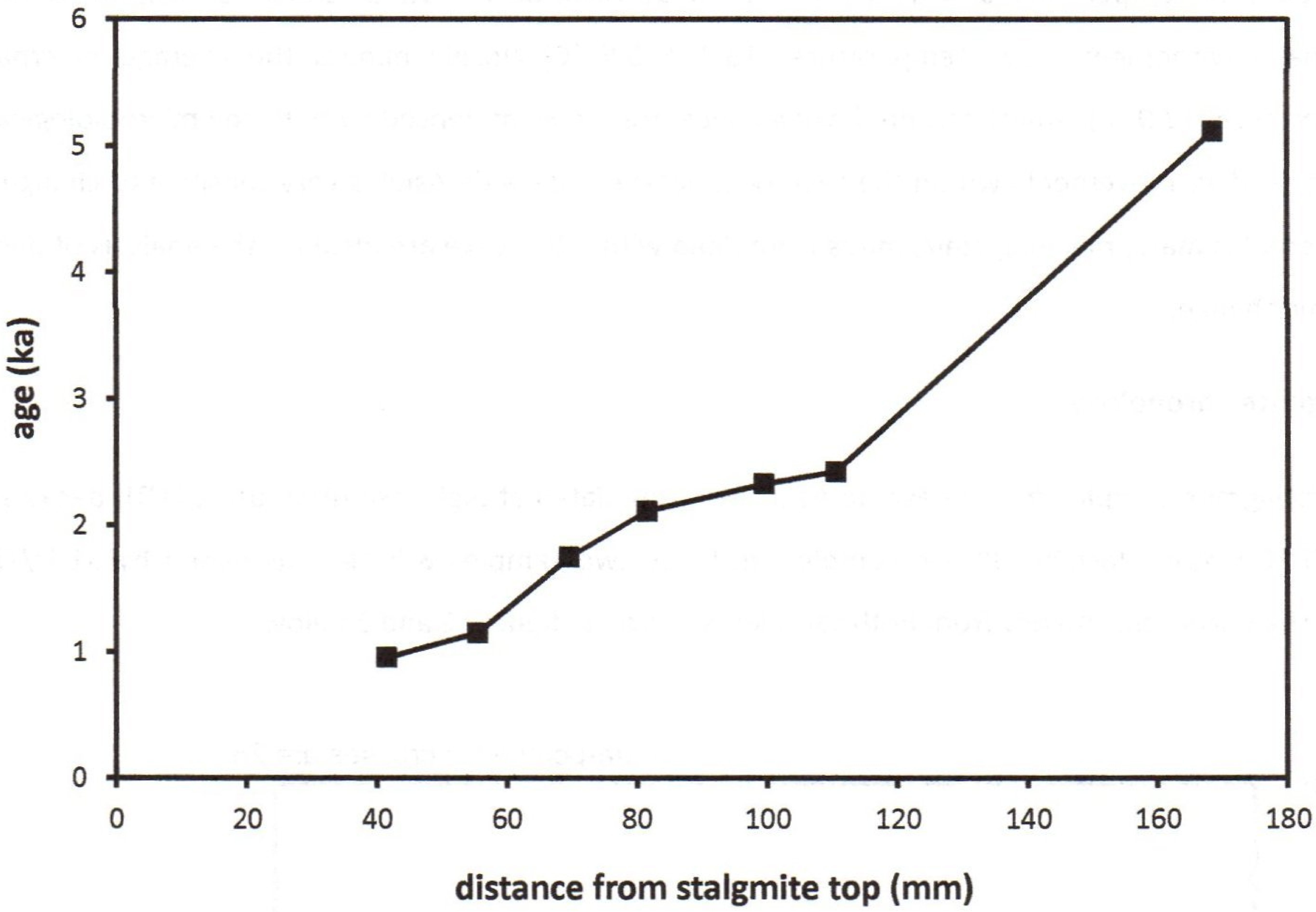

Figure 3: Preliminary age model for speleothem ASM developed from 7 U/Th analyses over 17cm of speleothem carbonate.

Stalagmite ASR has grown consistently throughout the Holocene and is approximately 12,000 years old. However, the second stalagmite (ASM) is of a much younger age and has so far been dated to 5000 years. The rate of growth is very fast (0.5 mm = approximately 20 years of growth), potentially allowing the recovery of an extremely detailed climate record (Figure 3).

Climate Change and Regional Significance

Stalagmite ASR has been analysed for stable isotopes (oxygen and carbon) and trace elements. The high resolution oxygen isotope profile from stalagmite ASR exhibits a series of distinct cycles. According to our current age model, oxygen isotope maxima (representing periods of rainfall minima) occur in phase with cold conditions identified in North Atlantic sediments by Bond et al., (1997) (Figure 4). This strong connection between climate in northern Iberia being driven by conditions within the North Atlantic is unique to these records from Cueva de Asiul.

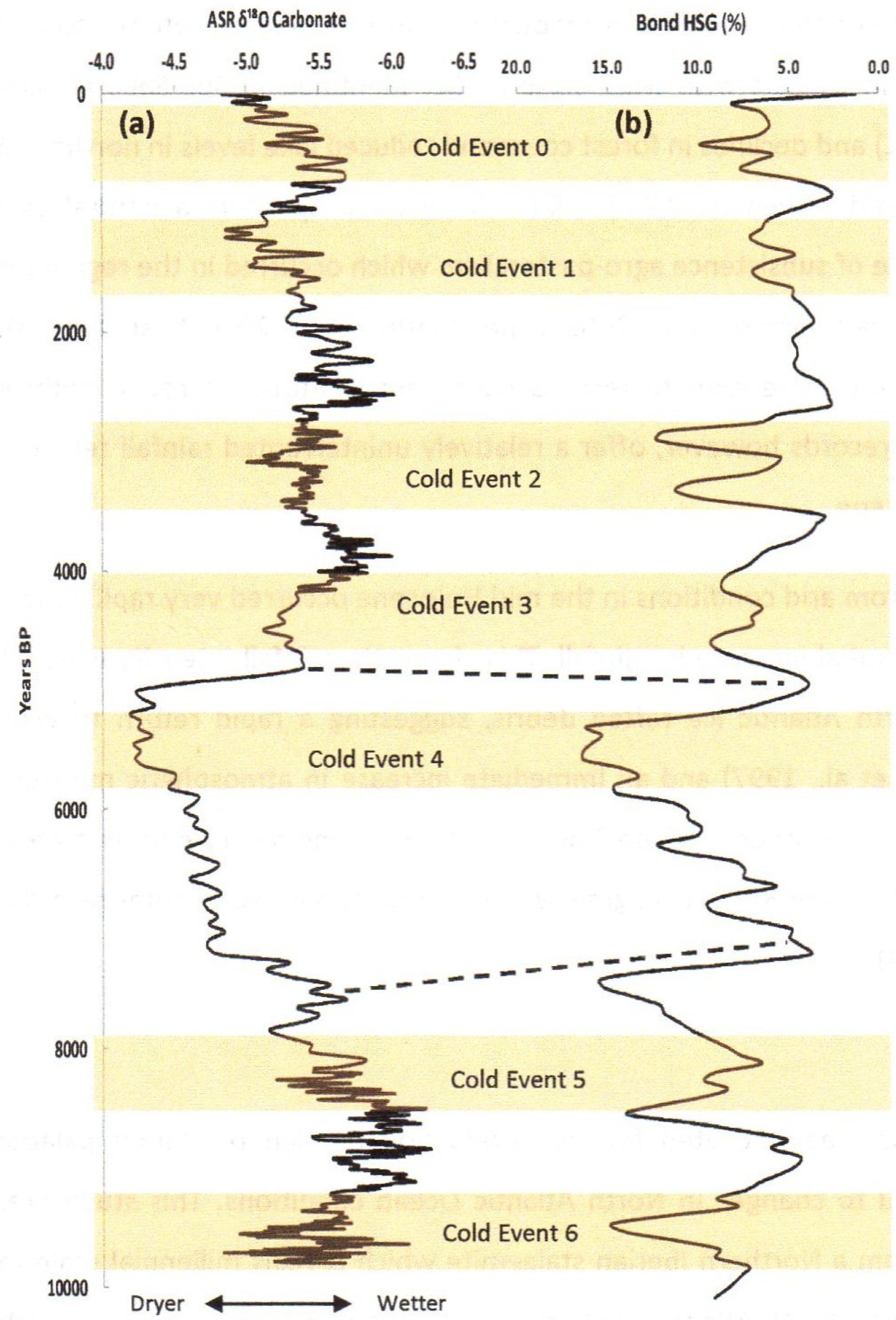

Figure 4: (**a**) ASR oxygen isotope record, comprising of 550 carbonate samples, 1 Stdv error of 0.08 ‰. U/Th age model is indicated alongside record. Orange boxes specify North Atlantic cold periods correlating with periods of significant drying in Northern Iberia. (**b**) Holocene drift ice record comprised of a smoothed and detrended stack of Haematite stained grain (HSG) percentage from ocean cores MC52-V29191+MC21-GGC22, data from Bond et al., (2001).

This stalagmite record indicates that the Early Holocene transition is marked by a decrease in oxygen isotopes, indicating a substantial increase in the amount of rainfall. These findings correlate well with existing records of climate change in northern Iberia which have identified the development of woodland ecosystems (Sobrino et al., 2005), increases in lake levels and a reduction in forest fire intensity during this period (Davis and Stevenson 2007).

During the middle of the Holocene, a gradual increase in oxygen isotopes towards lighter values indicates aridity, in concert with wide scale aridity identified in Sub-Saharan Africa (Gasse 2000, Barker et al., 2001) and declines in forest cover and reduced lake levels in northern Iberia (Sobrino et al., 2005, Davis and Stevenson 2007). Mid-Holocene aridity offers a natural explanation for the widespread uptake of subsistence agro-pastoralism which occurred in the region between 6700 and 5000 years BP (Pena-Chocarro et al., 2005, Lopez-Merino et al., 2010, Kaal et al., 2011). At the onset of agriculture, many palaeoclimate records have been disturbed through anthropogenic activity. These stalagmite records however, offer a relatively uninterrupted rainfall record which covers the mid to early Holocene.

Transition away from arid conditions in the mid Holocene occurred very rapidly, with isotopic values indicating a substantial increase in rainfall. This change in rainfall intensity is possibly correlated to reductions in North Atlantic ice rafted debris, suggesting a rapid return to warmer sea surface conditions (Bond et al., 1997) and an immediate increase in atmospheric moisture transport from the North Atlantic to southern Europe. The mid-late Holocene record demonstrates three periods of maximum rainfall (Figure 3), which agree with other palaeoenvironmental records from the region (Moreno et al., 2011).

Summary

Northern Iberia is ideally located for the production of high resolution palaeoclimate records, specifically related to changes in North Atlantic Ocean conditions. This study presents an oxygen isotope record from a Northern Iberian stalagmite which reveals millennial scale rainfall variability, closely correlated to North Atlantic cold phases and reductions in moisture availability. The record highlights a period of unprecedented aridification in the mid-Holocene, which may have been regionally important for human development around 6000 years BP and the onset of agro-pastoralism. Further work on the chronology is ongoing and will help constrain the timing of these changes. We hypothesise that the termination of aridity could be triggered by rapid oceanic and atmospheric reorganisation. More modern isotopic values suggest Northern Iberia is currently experiencing comparatively low levels of precipitation compared to the majority of the Holocene.

Acknowledgements

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